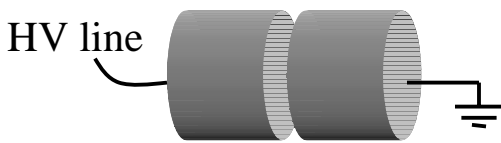


**ELECTRICAL BREAKDOWN IN A MARTIAN GAS MIXTURE.** C.R. Buhler<sup>1</sup>, C.I. Calle<sup>2</sup>, and E. Nelson<sup>3</sup>.  
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**Introduction:** The high probability for dust interactions during Martian dust storms and dust devils combined with the cold, dry climate of Mars most likely result in airborne dust that is highly charged. On Earth, potential gradients up to 5 kV/m have been recorded and in some cases resulted in lightning [1]. Although the Martian atmosphere is not conducive to lightning generation, it is widely believed that electrical discharge in the form of a corona occurs.

**Background:** In order to understand the breakdown of gases, Paschen measurements are taken which relate the minimum potential required to spark across a gap between two electrodes. The minimum potential is plotted versus the pressure-distance value for electrodes of a given geometry. For most gases, the potential decreases as the pressure decreases. For CO<sub>2</sub>, the minimum in the curve happens to be at Mars atmospheric pressures (5-7 mm Hg) for many distances and geometries. However, a very small amount (<0.1%) of mixing gases radically changes the curve, as noted by Leach [2]. Here, we present the first experimental results of a Paschen curve for a Mars gas mixture compared with 100% pure CO<sub>2</sub>.

**Procedure:** The experiments were performed at the Electrostatics and Material Physics Laboratory at the NASA Kennedy Space Center using a high vacuum system. Voltages of either positive or negative polarity were applied at one custom-made brass electrode while the other was grounded (see Figure 1.). The cylindrical electrodes have a diameter of 5.059 cm (2 in.) with curved edges to eliminate edge effects that create strong electric fields. Thus the electrodes fixed at 0.1 cm apart provided the parallel-plate geometry.

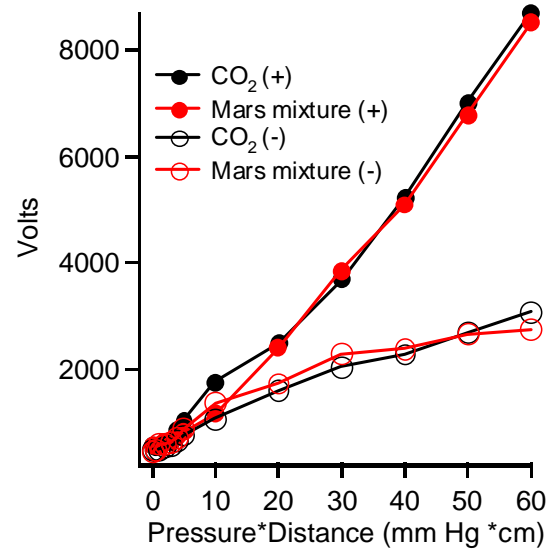


**Figure 1.** Schematic showing the parallel-plate geometry of the brass electrodes. High voltage was applied using both polarities.

The chamber was pumped down to  $10^{-4}$  mm Hg and backfilled to  $\sim 50$  mm Hg with the atmospheric gas. It was pumped down again to remove residual gases and contaminants. The gases that were used are 100% CO<sub>2</sub> and a Mars gas mixture provided by Praxair

Inc. that consisted of 95.5% carbon dioxide, 2.7% nitrogen, 1.6% argon, 0.13% oxygen and 0.07% carbon monoxide.

**Results:** Measurements were taken by simply increasing the voltage until the power supply shuts off as a result of the current divergence during breakdown. Figure 2 below shows the minimum voltage required for electrical breakdown of the two gases for both positive and negative polarities.

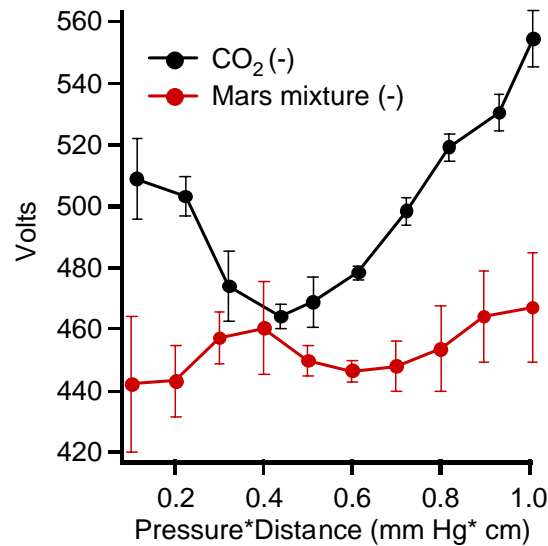


**Figure 2.** Minimum voltage required for breakdown for both gases using positive and negative polarities as a function of the pressure times distance relationship. (The error bars are smaller than the points.)

Clearly, as the pressure is lowered less voltage is required for breakdown to occur for both gases. At the higher pressures the spark potential does not seem to depend on the makeup of the gases but depends strongly on the polarity of the voltage applied. This is mainly due to the fact that CO<sub>2</sub> ionizes negatively. A negative potential electrode releases electrons from the metal that attach to the CO<sub>2</sub> molecule easily. These ionized molecules increase in number very rapidly and eventually form a current path to ground. However, a positive electrode does not release electrons and breakdown must occur using the more massive and slower positive ions in the gas. An excellent review of Paschen breakdown is given by von Engel [3] and Cobine [4].

However, at lower pressures, a clear difference in breakdown potentials can be seen. Figure 3 shows how the small concentrations of nitrogen, oxygen, argon and carbon monoxide greatly alter the Paschen curve for pressures ranging between 1 and 10 mm Hg. We can see that the minimum in the CO<sub>2</sub> curve at around 4-5 mm Hg becomes shifted to 6-7 mm Hg once the other gases are added. This suggests that even though breakdown occurs easily at Mars pressures, it may not occur at the minimum in the Paschen curve for CO<sub>2</sub>. Instead the results seem to indicate that there may actually be a local maximum near the minimum in the CO<sub>2</sub> curve.

Once the pressure is lowered below 1 mm Hg (not shown), both the CO<sub>2</sub> and Mars gas mixture rise again since there are no molecules to ionize in a hard vacuum.



**Figure 3.** Minimum spark potential in the range 1-10 mm Hg for pure CO<sub>2</sub> and the Mars gas mixture using negative polarity brass electrodes at 0.1 cm apart.

It is interesting to note that at around Mars pressures, the blue spark seen at higher pressures turns into a purple-blue corona. At pressures less than 2 mm Hg, there is no longer a well-defined spark between the cylinders, instead there is only the corona breakdown to the gas around the charged electrode.

It should be noted that Paschen curves are experimental and depend on several factors such as gas content, pressure, distance, geometry, wind velocity, electrode composition, etc. Thus true Paschen measurements should only be performed on Mars. However, we have shown that differences can be seen experimentally on Earth and that using a Mars mixture gas should be more accurate than pure CO<sub>2</sub>.

**Discussion:** It is expected from such low values given by the Paschen curve that discharge should occur

very frequently on Mars. Even though discharge in any form has not been detected on Mars, Eden and Vonnegut [5] showed that sand in a low pressure CO<sub>2</sub> environment can triboelectrically charge above the Paschen limit and result in glow discharges and sparks. In their experiment a small amount of sand (~ 50 g) was placed in an evacuated flask and backfilled up to 10 mm Hg with CO<sub>2</sub>. It was then shaken by hand in the dark to observe the low intensity discharges. The dominant colors observed were blue and red in their experiment.

We recently redid this experiment but replaced CO<sub>2</sub> with the Mars gas mixture and replaced the sand with JSC Mars-1 Martian simulant [6]. Dry simulant (baked at 180°C for several days) was placed inside the evacuated flask under vacuum. After backfilling to 10 mm Hg, a stopper was used to enclose it before being removed from the chamber. After a few minutes in the dark room, the flask was shaken vigorously and several discharges were observed. Approximately 90% of the sparks observed were green and the rest were blue/purple. This was in stark contrast to Eden and Vonnegut's result in which the colors observed from red to blue.

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**References:** [1]. Crozier, W. D., "The Electric Field of a New Mexico Dust Devil", *JGR*, **69**, 5427 (1964). [2] Leach, R. N., Sand and Dust on Mars, *NASA Conference Publication 10074*, 36 (1991). [3] von Engel, A., *Ionized Gases*, American Institute of Physics, New York, 1994. [4] Cobine, J. D., *Gaseous Conductors: Theory and Engineering Applications*, Dover, New York, 1958. [5] Eden, H. F. and B. Vonnegut, "Electrical Breakdown Caused by Dust Motion in Low-Pressure Atmospheres: Considerations for Mars", *Science*, **180**, 962-963 (1973). [6] Allen, C., Jager, K., Morris, R., Lindstrom, D., Lindstrom, M., and Lockwood, J., "JSC Mars-1: A Martian Soil Simulant" *Proceedings of the Conference American Society of Civil Engineers*, Albuquerque, NM, 469-476 (1998).